

Hepatoprotective effects of systemic ER activation

ChIPseq/Epigenome genome - Enhancer-gene pair analysis

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16 September, 2022

```
library(tidyverse)
```

Use BEDOPS suite to determine the closest TSS to the enhancer sites. Run this in terminal, may adjust paths. Requires BEDOPS and bedtools.

```
#Import the closest genes as determined by
closest <- read.delim("results/Epigenome_analysis/origin_closest1_left_closest_1_2_right.bed", header=F)
enhancer_ID <- c(1:1816)
# Row 738 has an NA in several columns (including V8), remove this one as it causes issues downstream.
closest2 <- closest %>%
  separate(col = V3, into = c("V3_left", "V3_right"), sep = "\\|") %>%
  separate(col = V5, into = c("V5_left", "V5_right"), sep = "\\|") %>%
  separate(col = V7, into = c("V7_left", "V7_right"), sep = "\\|") %>%
  mutate(enhancer_ID=enhancer_ID) %>%
  filter(!is.na(V8))

closest3 <- closest2 %>% mutate(enha.ident = paste0(V1, ".", V2, ".", V3_left), .before = V1)

colnames(closest3) <- c("enha.ident", "ori_chrom", "ori_start", "ori_end", "left_1_chrom", "left_1_start",
  "right_1_chrom", "right_1_start", "right_1_end",
  "right_2_chrom", "right_2_start", "right_2_end", "enhancer_ID")

closest_ori <- closest3 %>% dplyr::select(1, 14, 2:4) %>% mutate(query_ID = "closest_ori")
colnames(closest_ori) <- c("loc_ID", "enha.ID", "chrom", "start", "end", "query_ID")
closest_left1 <- closest3 %>% dplyr::select(1, 14, 5:7) %>% mutate(query_ID = "closest_left1")
colnames(closest_left1) <- c("loc_ID", "enha.ID", "chrom", "start", "end", "query_ID")

closest_right1 <- closest3 %>% dplyr::select(1, 14, 8:10) %>% mutate(query_ID = "closest_right1")
colnames(closest_right1) <- c("loc_ID", "enha.ID", "chrom", "start", "end", "query_ID")
closest_right2 <- closest3 %>% dplyr::select(1, 14, 11:13) %>% mutate(query_ID = "closest_right2")
colnames(closest_right2) <- c("loc_ID", "enha.ID", "chrom", "start", "end", "query_ID")

closest_long <- rbind(closest_ori, closest_left1,
  closest_right1, closest_right2)
```

```
#subset the enhancer_df to have the exact locations in three columns for later
location <- closest_ori %>% dplyr::select(1,3,4,5)
```

Annotate the closest genes

```
library("ChIPpeakAnno")
library("GenomicRanges")
options(connectionObserver = NULL) #That is a work-around, as the org.Mm. package cannot be loaded
library("org.Mm.eg.db")
library("biomaRt")

gr_closest_long <- makeGRangesFromDataFrame(closest_long, start.field = "start", end.field = "end", ignore.strand = TRUE)
names(gr_closest_long) <- c(1:length(gr_closest_long))
```

Annotate the TSS

```
listEnsemblArchives()
```

```
##           name      date                url version
## 1  Ensembl GRCh37 Feb 2014      https://grch37.ensembl.org GRCh37
## 2    Ensembl 107 Jul 2022 https://jul2022.archive.ensembl.org    107
## 3    Ensembl 106 Apr 2022 https://apr2022.archive.ensembl.org    106
## 4    Ensembl 105 Dec 2021 https://dec2021.archive.ensembl.org    105
## 5    Ensembl 104 May 2021 https://may2021.archive.ensembl.org    104
## 6    Ensembl 103 Feb 2021 https://feb2021.archive.ensembl.org    103
## 7    Ensembl 102 Nov 2020 https://nov2020.archive.ensembl.org    102
## 8    Ensembl 101 Aug 2020 https://aug2020.archive.ensembl.org    101
## 9    Ensembl 100 Apr 2020 https://apr2020.archive.ensembl.org    100
## 10   Ensembl 99 Jan 2020 https://jan2020.archive.ensembl.org     99
## 11   Ensembl 98 Sep 2019 https://sep2019.archive.ensembl.org     98
## 12   Ensembl 97 Jul 2019 https://jul2019.archive.ensembl.org     97
## 13   Ensembl 96 Apr 2019 https://apr2019.archive.ensembl.org     96
## 14   Ensembl 95 Jan 2019 https://jan2019.archive.ensembl.org     95
## 15   Ensembl 94 Oct 2018 https://oct2018.archive.ensembl.org     94
## 16   Ensembl 93 Jul 2018 https://jul2018.archive.ensembl.org     93
## 17   Ensembl 92 Apr 2018 https://apr2018.archive.ensembl.org     92
## 18   Ensembl 91 Dec 2017 https://dec2017.archive.ensembl.org     91
## 19   Ensembl 90 Aug 2017 https://aug2017.archive.ensembl.org     90
## 20   Ensembl 80 May 2015 https://may2015.archive.ensembl.org     80
## 21   Ensembl 77 Oct 2014 https://oct2014.archive.ensembl.org     77
## 22   Ensembl 75 Feb 2014 https://feb2014.archive.ensembl.org     75
## 23   Ensembl 54 May 2009 https://may2009.archive.ensembl.org     54
##      current_release
## 1
## 2      *
## 3
## 4
## 5
```

```
## 6
## 7
## 8
## 9
## 10
## 11
## 12
## 13
## 14
## 15
## 16
## 17
## 18
## 19
## 20
## 21
## 22
## 23
```

```
mart <- useMart(biomart = "ensembl", dataset = "mmusculus_gene_ensembl", host = "https://sep2019.archive.fo
annoDataMart <- getAnnotation(mart, featureType = "TSS")
```

Annotate the TSS

```
gr_closest_long_anno <- annotatePeakInBatch(gr_closest_long,
      AnnotationData=annoDataMart,
      featureType = "TSS",
      output="nearestLocation",
      PeakLocForDistance = "start")

gr_closest_long_anno <- as.data.frame(gr_closest_long_anno)
```

Import the gene expression data

```
getwd()
```

```
## [1] "/Users/christian.som/GitHub/MAFLD_ER_agonists"
```

```
source("code/00_helper_functions.R")
symbol_geneID <- read.delim("data/ensembl_mmus_sep2019_annotation.tsv")[,1:2]

raw_counts <- read.table(
  file = 'data/bulkRNAseq_mmus_rawcounts.tsv',
  stringsAsFactors = FALSE,
  sep = '\t',
  header = TRUE) %>%
  dplyr::select(-PPT_HFD_male_4) %>%
  tibble::column_to_rowname('geneID') %>%
```

```

as.matrix()

gene_len <- read.table(
  file = 'data/bulkRNAseq_mmus_gene_lengths.tsv',
  stringsAsFactors = FALSE,
  sep = '\t',
  header = TRUE)

TPM <- normalizeData(x=raw_counts, len = gene_len$length, method = "TPM") %>%
  tibble::rownames_to_column("ensembl_gene_id")

TPM <- TPM %>%
  dplyr::select(ensembl_gene_id, CD_male_1, CD_male_4, HFD_male_2,HFD_male_1,DPN_HFD_male_1, DPN_HFD_ma
TPM <- inner_join(symbol_geneID, TPM, by="ensembl_gene_id")

# We name the mice according to their original mouse number instead of replicate number.
# CD2 and CD9 correspond to CDm1 and CDm4, HFD3 and HFD4 correspond to HFDm2 and HFDm1, DPN2 and DPN3 c

colnames(TPM) <- c("ensembl_gene_id", "symbol", "CDm2", "CDm9", "HFDm3", "HFDm4","DPN2", "DPN3", "E2_8"

gr_closest_long_anno_closest_genes <- gr_closest_long_anno %>%
  filter(!query_ID=="closest_ori") %>%
  dplyr::rename("ensembl_gene_id"="feature")

gr_closest_long_anno_closest_genes <- as.data.frame(gr_closest_long_anno_closest_genes)

TPM_filt <- TPM %>%
  dplyr::filter(ensembl_gene_id%in%gr_closest_long_anno_closest_genes$ensembl_gene_id)

chrom_TPM <- inner_join(gr_closest_long_anno_closest_genes, TPM_filt, by= "ensembl_gene_id") # 2 entrie

chrom_TPM2 <- chrom_TPM %>%
  dplyr::select("loc_ID" ,"seqnames", "start", "end", "enha.ID", "query_ID", "symbol", "ensembl_gene_id

```

IMPORT ENHANCER COUNTS and normalize table

```

library(dplyr)
library(tidyr)

counts_enha <- read.delim("results/Epigenome_analysis/diffbind_enhancers_1816_H3K27ac.clean.readCount",
names(counts_enha) <- c("CDm2_K27ac","CDm9_K27ac","HFDm3_K27ac","HFDm4_K27ac", "DPN2_K27ac","DPN3_K27ac"
colsums_enha <- colSums(counts_enha[,])

counts_enha_norm <- sweep(counts_enha, 2, colsums_enha, FUN = "/")
counts_enha_norm2 <- counts_enha_norm *10^6
colSums(counts_enha_norm2[,])

```

```

##  CDm2_K27ac  CDm9_K27ac HFDm3_K27ac HFDm4_K27ac  DPN2_K27ac  DPN3_K27ac
##      1e+06      1e+06      1e+06      1e+06      1e+06      1e+06
##  E2_8_K27ac  E2_9_K27ac
##      1e+06      1e+06

```

```
counts_enha_norm2.1 <- counts_enha_norm2 %>% rownames_to_column("loc_ID")
K27_GE_joined <- inner_join(chrom_TPM2, counts_enha_norm2.1, by="loc_ID")
View(K27_GE_joined)
```

Subset the enhancer table and put into long format

```
sub_GE.K27_GE_joined <- K27_GE_joined %>%
  dplyr::select("loc_ID", "query_ID", "symbol", "CDm2", "CDm9", "HFDm3", "HFDm4", "DPN2", "DPN3", "E2_8", "E2_9")
sub_GE.K27_GE_long <- pivot_longer(sub_GE.K27_GE_joined, cols=4:11, values_to = "Gene_expression")

sub.K27_K27_GE_joined <- K27_GE_joined %>%
  dplyr::select("loc_ID", "query_ID", "ensembl_gene_id", "CDm2_K27ac", "CDm9_K27ac", "HFDm3_K27ac", "HFDm4_K27ac")
sub.K27_K27_GE_long <- pivot_longer(sub.K27_K27_GE_joined, cols=4:11, values_to = "H3K27ac")

K27_GE_long <- cbind(sub_GE.K27_GE_long, sub.K27_K27_GE_long)

K27_GE_long_dd <- K27_GE_long[!duplicated(as.list(K27_GE_long))]

# Remove the zeros to not correlate zeros (gives error message - but these genes are removed later anyway)
K27_GE_long_dd <- K27_GE_long_dd %>%
  group_by(loc_ID, symbol) %>%
  mutate(filter_zeros = mean(Gene_expression)) %>%
  filter(filter_zeros > 0) %>%
  dplyr::select(!filter_zeros)
```

Import the reverted gene sets and filter the tables

```
K27_GE_long_group <- K27_GE_long_dd %>% group_by(loc_ID, query_ID) %>%
  mutate(correlation_pearson = cor(Gene_expression, H3K27ac, method="pearson")) %>%
  mutate(correlation_spearman = cor(Gene_expression, H3K27ac, method="spearman"))

write.table(K27_GE_long_group, "results/Epigenome_analysis/K27_GE_corr_before_filtering.txt", quote=F, as.is=T)

DEGsets <- readRDS("results/bulkRNAseq_mmus_DEG_sets.rds")
revALL <- DEGsets$gene_id$reverted
length(revALL)
```

```
## [1] 379
```

```
K27_GE_long_rev_insect <- K27_GE_long_group %>%
  filter(ensembl_gene_id %in% revALL)
length(unique(K27_GE_long_rev_insect$ensembl_gene_id))
```

```
## [1] 107
```

```

K27_GE_long_group_plot_pearson <- K27_GE_long_rev_insect %>%
  filter(abs(correlation_pearson) > 0.75) %>%
  group_by(loc_ID, query_ID) %>%
  mutate(name.ident = paste0(symbol, "_", loc_ID))

K27_GE_long_group_plot_pearson_revCount <- K27_GE_long_group_plot_pearson %>%
  mutate(name.ident = paste0(loc_ID, ":", symbol))

K27_GE_long_group_plot_spearman <- K27_GE_long_rev_insect %>%
  filter(abs(correlation_spearman) > 0.75) %>% group_by(loc_ID, query_ID) %>%
  mutate(name.ident = paste0(symbol, "_", loc_ID))

K27_GE_long_group_plot_pearson_before_Rev <- K27_GE_long_group %>%
  filter(abs(correlation_pearson) > 0.75) %>% group_by(loc_ID, query_ID) %>%
  mutate(name.ident = paste0(symbol, "_", loc_ID))

K27_GE_long_group_plot_spearman_before_Rev <- K27_GE_long_group %>%
  filter(abs(correlation_spearman) > 0.75) %>% group_by(loc_ID, query_ID) %>%
  mutate(name.ident = paste0(symbol, "_", loc_ID))

```

#Add 50kb to intersect CTCF peaks with the H3K27ac peaks

```

K27_GE_long_group_coordinates <- inner_join(K27_GE_long_group_plot_pearson, location, by="loc_ID")
K27_GE_long_group_coordinates$end <- as.integer(K27_GE_long_group_coordinates$end)

K27_GE_long_group_coordinates_left <- K27_GE_long_group_coordinates %>%
  dplyr::filter(query_ID=="closest_left1") %>%
  mutate(new_end = end+50000) %>%
  mutate(new_start=start)

K27_GE_long_group_coordinates_right <- K27_GE_long_group_coordinates %>%
  dplyr::filter(query_ID=="closest_right1" | query_ID=="closest_right2") %>%
  mutate(new_start = start-50000) %>%
  mutate(new_end=end)

K27_GE_long_group_coordinates_left_export <- K27_GE_long_group_coordinates_left %>%
  dplyr::select("chrom", "new_start", "new_end", "loc_ID", "query_ID", "symbol") %>%
  unique()

K27_GE_long_group_coordinates_right_export <- K27_GE_long_group_coordinates_right %>%
  dplyr::select("chrom", "new_start", "new_end", "loc_ID", "query_ID", "symbol") %>%
  unique()

write.table(K27_GE_long_group_coordinates_left_export, "results/Epigenome_analysis/H3K27ac_left_non_inte
write.table(K27_GE_long_group_coordinates_right_export, "results/Epigenome_analysis/H3K27ac_right_non_i

#From here, intersect the CTCF peaks with the exported H3K27ac regions using BEDtools (command line)

```

prepare the CTCF files - separate by motif-orientation.

```
#load the motif-discovery file of CTCF motifs in mm10 genome by FIMO
FIMO_CTCF <- read.delim("data/fimo_mm10_genome_CTCFscan.tsv", sep="\t")

FIMO_CTCF_plus_bed <- FIMO_CTCF %>%
  dplyr::filter(strand=="+") %>%
  dplyr::select("chrom"="sequence_name", "start", "end"="stop", "strand")

FIMO_CTCF_minus_bed <- FIMO_CTCF %>%
  dplyr::filter(strand=="-") %>%
  dplyr::select("chrom"="sequence_name", "start", "end"="stop", "strand")

write.table(FIMO_CTCF_plus_bed, "results/Epigenome_analysis/fimo_mm10_genome_CTCF_plus.bed", quote=F, r
write.table(FIMO_CTCF_minus_bed, "results/Epigenome_analysis/fimo_mm10_genome_CTCF_minus.bed", quote=F,
```

HERE, RUN THE SHELL SCRIPT “Epigenome_06.03_CTCF_script_bedtools_enh_intersect.sh”

#after BEDTools intersection of H3K27ac enhancers (that have a good correlation with nearby genes) with nearby CTCF peaks, re-import

```
library(tidyverse)

names <- c("chrom", "start", "end", "loc_ID", "query_ID", "symbol")
H3K27ac_left_CTCFx_outwards <- read.delim("results/Epigenome_analysis/H3K27ac_left_CTCF.intersect.noncan
H3K27ac_left_CTCFx <- read.delim("results/Epigenome_analysis/H3K27ac_left_CTCF.intersect.canon.uniq.bed
H3K27ac_right_CTCFx_outwards <- read.delim("results/Epigenome_analysis/H3K27ac_right_CTCF.intersect.non
H3K27ac_right_CTCFx <- read.delim("results/Epigenome_analysis/H3K27ac_right_CTCF.intersect.canon.uniq.b
```

#combine these data.frames, because they comprise the enhancer-gene pairs that we can report

```
H3K27ac_CTCF_intersect <- rbind(H3K27ac_left_CTCFx_outwards, H3K27ac_left_CTCFx, H3K27ac_right_CTCFx_ou
table(H3K27ac_CTCF_intersect$CTCF_pos)
```

```
##
## canonical  outwards
##           50         33
```

```
length(unique(H3K27ac_CTCF_intersect$loc_ID))
```

```
## [1] 67
```

```
unique_symbols <- unique(H3K27ac_CTCF_intersect$symbol)
length(unique_symbols)
```

```
## [1] 45
```

```
# 45 unique genes that underlie potential enhancer-mediated estrogen-dependent regulation
```

#Compare the fold-change values for these sites - in addition to the reads in peaks this gives information about how much these enhancers are changed

```
CDvsHFD_H3K27ac_Diffbind <- readRDS("results/Epigenome_analysis/Diffbind_results_FDR_fold.rds")$all_DB_
mutate(loc_ID = paste0(seqnames, ".",start,".",end), .before = seqnames) %>%
  dplyr::select(loc_ID, Fold, FDR)
```

```
# These are the enhancers intersected with CTCF. But more informative with foldchanges from Diffbind. T
H3K27ac_CTCF_intersect_log2FC <- inner_join(H3K27ac_CTCF_intersect,CDvsHFD_H3K27ac_Diffbind, by="loc_ID"
```

```
# Retrieves the unique person corr values from BEFORE the CTCF intersection
corr_values <- K27_GE_long_group_plot_pearson %>%
  ungroup() %>%
  dplyr::select("loc_ID", "correlation_pearson", "symbol") %>%
  unique() %>% group_by(symbol)
```

```
# Creates a dataframe between the corr values and log2FCs. This one is the COMPLETE dataframe
H3K27ac_CTCF_intersect_log2FC_corr <- inner_join(corr_values, H3K27ac_CTCF_intersect_log2FC, by=c("loc_
duplicated(H3K27ac_CTCF_intersect_log2FC_corr)
```

```
## [1] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [13] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [25] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [37] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [49] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [61] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [73] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
```

```
length(unique(H3K27ac_CTCF_intersect_log2FC_corr$symbol))
```

```
## [1] 45
```

```
# This unique ID is necessary to join the data frames in the next section. Otherwise, enhancers that ar
H3K27ac_CTCF_intersect_log2FC_corr <- H3K27ac_CTCF_intersect_log2FC_corr %>%
  mutate(name.ident = paste0(loc_ID, ":", symbol))
```

```
# To plot, we need the single columns for gene expression and log2FC again. Note: some enhancers have
K27_GE_long_group_plot_filt <- K27_GE_long_group_plot_pearson %>%
  group_by(symbol, loc_ID) %>%
  mutate(name.ident = paste0(loc_ID, ":", symbol)) %>%
  filter(name.ident%in%H3K27ac_CTCF_intersect_log2FC_corr$name.ident)
```

```
K27_GE_long_group_plot_filt <- K27_GE_long_group_plot_filt[!duplicated(K27_GE_long_group_plot_filt), ]
length(unique(K27_GE_long_group_plot_filt$symbol))
```

```
## [1] 45
```



```

# The following should yield "character(0)"
setdiff(K27_GE_long_group_plot_filt$symbol, H3K27ac_CTCF_intersect_log2FC_corr$symbol)

## character(0)

length(unique(K27_GE_long_group_plot_filt$symbol)) # 45 unique genes

## [1] 45

nrow(K27_GE_long_group_plot_filt)/8 # 68 enhancer - gene pairs

## [1] 68

length(unique(K27_GE_long_group_plot_filt$loc_ID)) # 67 unique enhancers

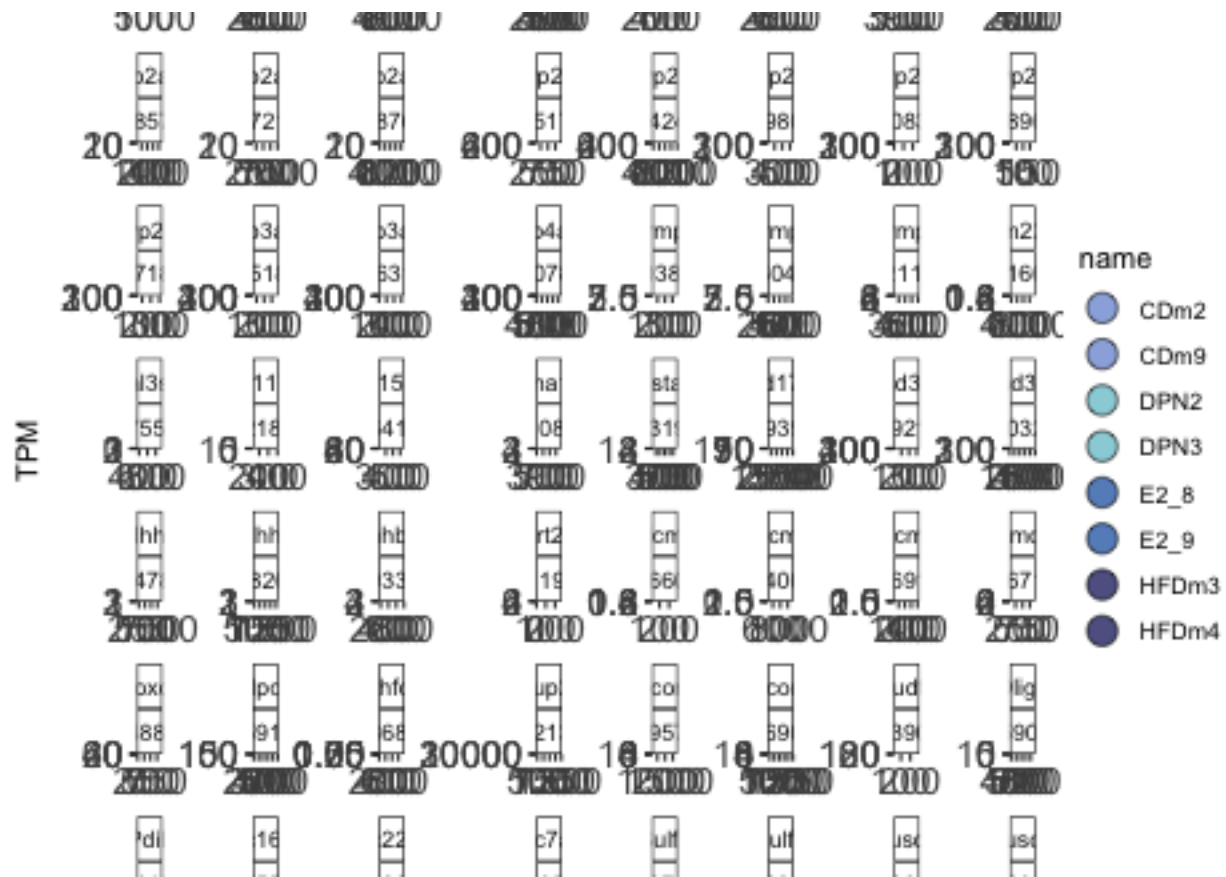
## [1] 67

# 68 total combinations of location IDs and genes, one enhancer goes for to genes.

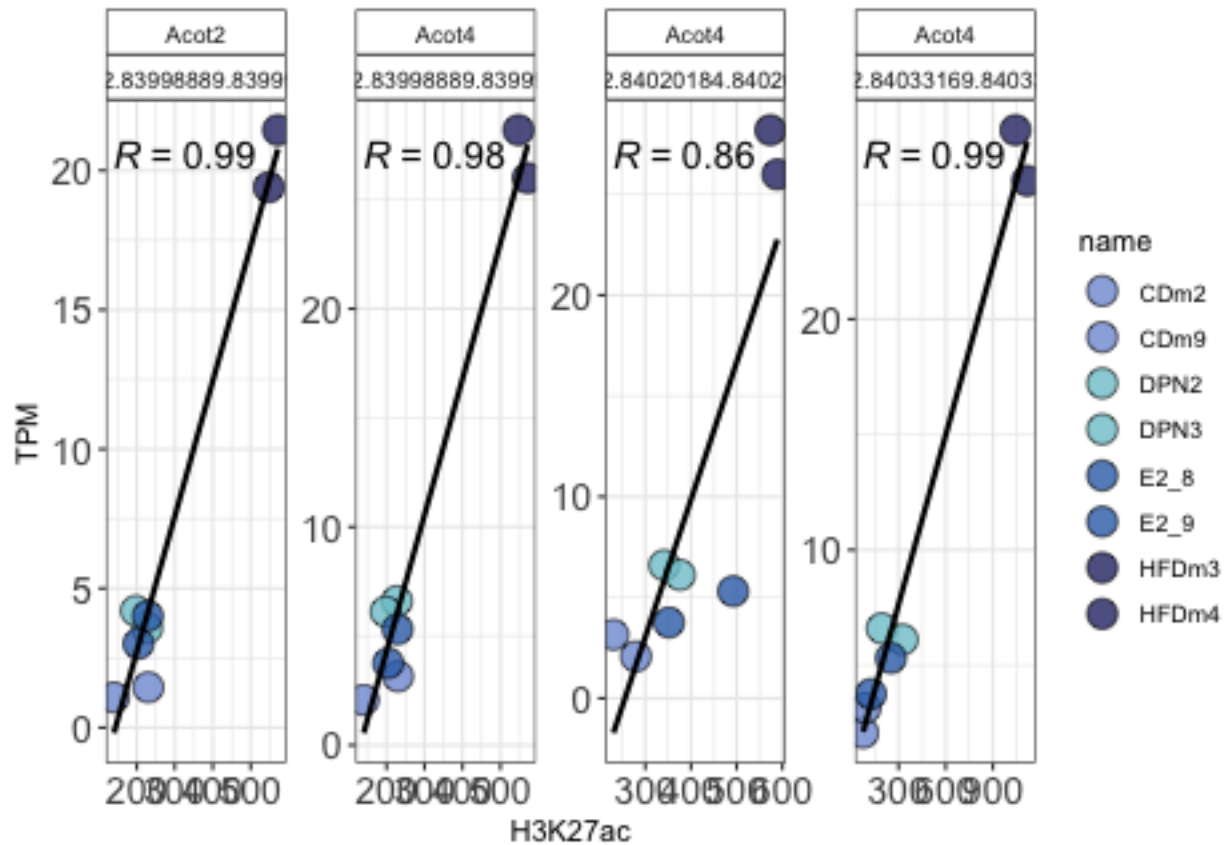
write.table(K27_GE_long_group_plot_filt, "results/Epigenome_analysis/corr_45genes_67enh_toPlot.txt", row.names=FALSE, col.names=FALSE, as.is=TRUE)

library(ggpubr)
ggscatter(K27_GE_long_group_plot_filt, x = "H3K27ac", y="Gene_expression", add = "reg.line",
          shape=21,size=5, fill="name",alpha=0.8,
          # yscale = "log2",
          # xscale = "log2",
          xlab="H3K27ac",
          ylab="TPM",
          palette=c("#7f9ad7","#7f9ad7", "#7dc7d1", "#7dc7d1", "#356fb5","#356fb5","#2c2f72","#2c2f72"),
          stat_cor(aes(label = ..r.label..),method="pearson", p.digits=0, size=5) +
  theme_bw() +
  theme(axis.text = element_text(size=14),
        strip.background = element_rect(colour="black",
                                          fill="white")) +
  facet_wrap(vars(symbol, loc_ID), scales = "free", ncol=8)

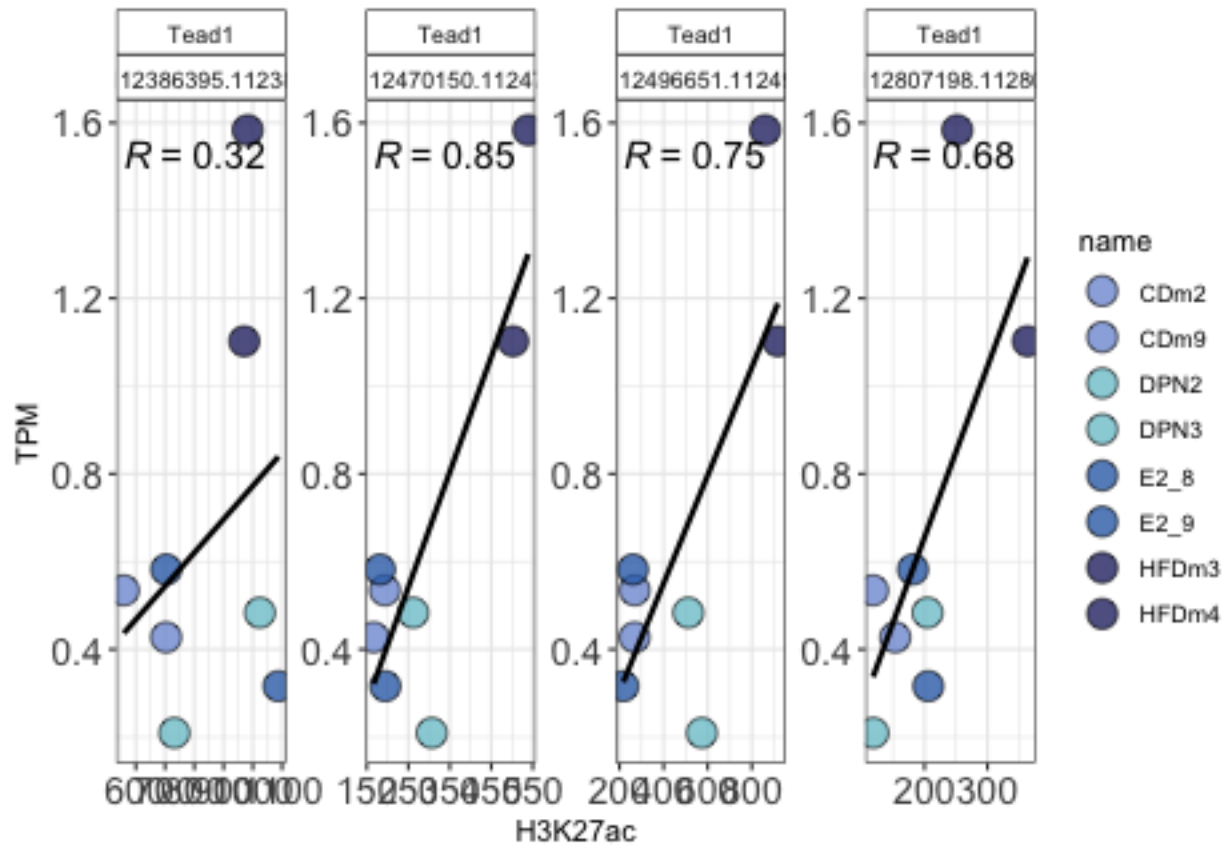
```



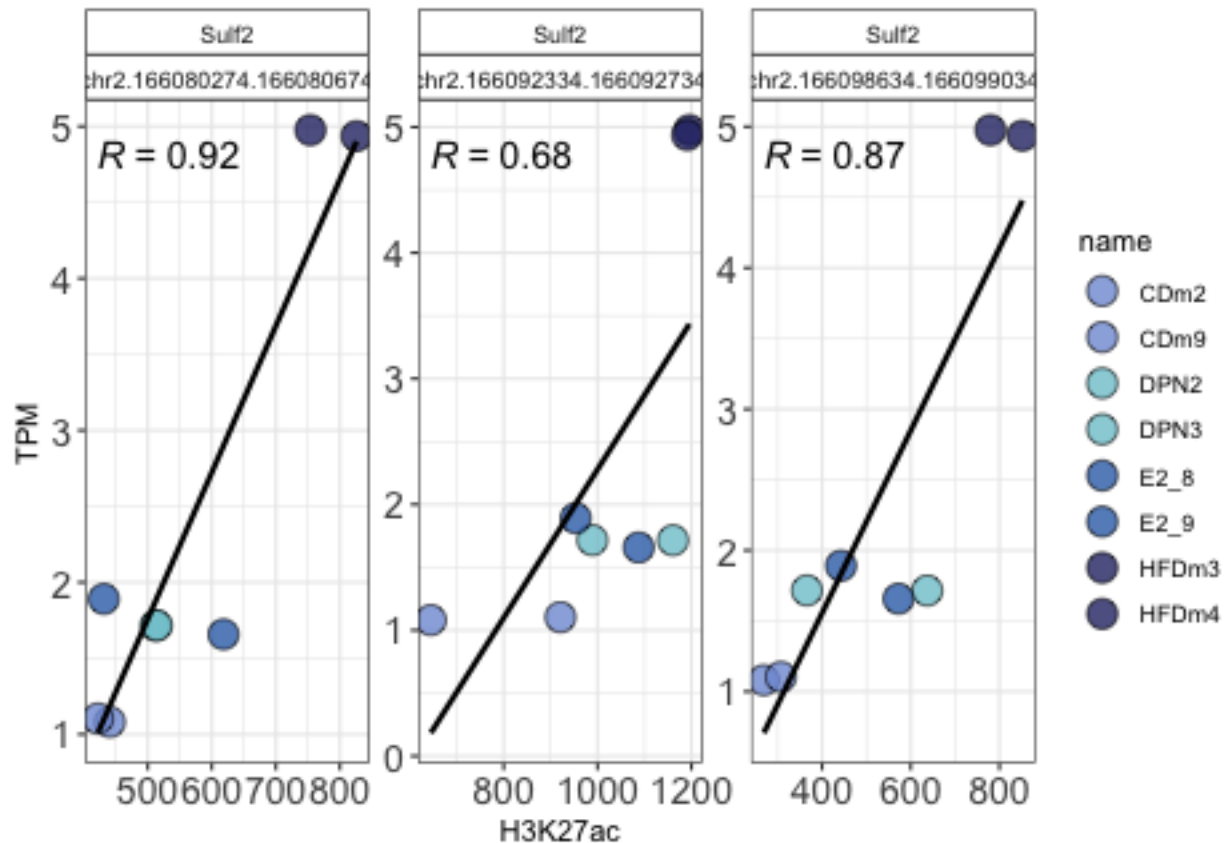
```
Acot_filt <- K27_GE_long_group_plot_filt %>% dplyr::filter(grepl("Acot", symbol))
ggscatter(Acot_filt, x = "H3K27ac", y="Gene_expression", add = "reg.line",
  shape=21,size=5, fill="name",alpha=0.8,
  # yscale = "log2",
  # xscale = "log2",
  xlab="H3K27ac",
  ylab="TPM",
  palette=c("#7f9ad7","#7f9ad7", "#7dc7d1", "#7dc7d1", "#356fb5","#356fb5","#2c2f72","#2c2f72",
  stat_cor(aes(label = ..r.label..),method="pearson", p.digits=0, size=5) +
  theme_bw() +
  theme(axis.text = element_text(size=14),
    strip.background = element_rect(colour="black",
      fill="white")) +
  facet_wrap(vars(symbol, loc_ID), scales="free", ncol=4)
```



```
# plot Tead1
tead1 <- K27_GE_long_group %>% dplyr::filter(symbol=="Tead1") %>% filter(!loc_ID=="chr7.112688427.112688427")
# note: this loc_ID is filtered out because it does not have a CTCF peak closeby (at least not a significant one)
#tead1_filt <- K27_GE_long_group_plot_filt %>% dplyr::filter(symbol=="Tead1") # Plot this to only show Tead1
ggscatter(tead1, x = "H3K27ac", y="Gene_expression", add = "reg.line",
  shape=21,size=5, fill="name",alpha=0.8,
  # yscale = "log2",
  # xscale = "log2",
  xlab="H3K27ac",
  ylab="TPM",
  palette=c("#7f9ad7","#7f9ad7", "#7dc7d1", "#7dc7d1", "#356fb5", "#356fb5", "#2c2f72", "#2c2f72"),
  stat_cor(aes(label = ..r.label..),method="pearson", p.digits=0, size=5) +
  theme_bw() +
  theme(axis.text = element_text(size=14),
    strip.background = element_rect(colour="black",
      fill="white")) +
  facet_wrap(vars(symbol, loc_ID), scales="free", ncol=4)
```



```
# One enhancer has a correlation of 0.67 and hence does not pass the filter. I think this enhancer is i
Sulf2_also_non_filter_pass <- K27_GE_long_group %>% dplyr::filter(symbol=="Sulf2") %>% filter(!loc_ID==
Sulf2_all_enhancers <- K27_GE_long_group %>% dplyr::filter(symbol=="Sulf2")
#Sulf2 <- K27_GE_long_group_plot_filt %>% dplyr::filter(symbol=="Sulf2") # Plot this to only show E-G-
ggscatter(Sulf2_also_non_filter_pass, x = "H3K27ac", y="Gene_expression", add = "reg.line",
          shape=21,size=5, fill="name",alpha=0.8,
          # yscale = "log2",
          # xscale = "log2",
          xlab="H3K27ac",
          ylab="TPM",
          palette=c("#7f9ad7","#7f9ad7", "#7dc7d1", "#7dc7d1", "#356fb5","#356fb5","#2c2f72","#2c2f72",
stat_cor(aes(label = ..r.label..),method="pearson", p.digits=0, size=5) +
theme_bw() +
theme(axis.text = element_text(size=14),
      strip.background = element_rect(colour="black",
                                       fill="white")) +
facet_wrap(vars(symbol, loc_ID), scales="free", ncol=4)
```



Plot histogram to show in which processes (of the 24 GSEA) the 45 genes fall into.

```
library(clusterProfiler)
K27_GE_long_group_plot_filt <- read.delim("results/Epigenome_analysis/corr_45genes_67enh_toPlot.txt")
length(unique(K27_GE_long_group_plot_filt$symbol))
```

```
## [1] 45
```

```
symbols <- K27_GE_long_group_plot_filt$symbol %>% unique()

reactome_pathways <- readRDS("results/bulkRNAseq_mmus_GSEA_reactome_cluster_sets.rds")
reactome_pathways.2 <- as.data.frame(do.call(cbind, reactome_pathways))

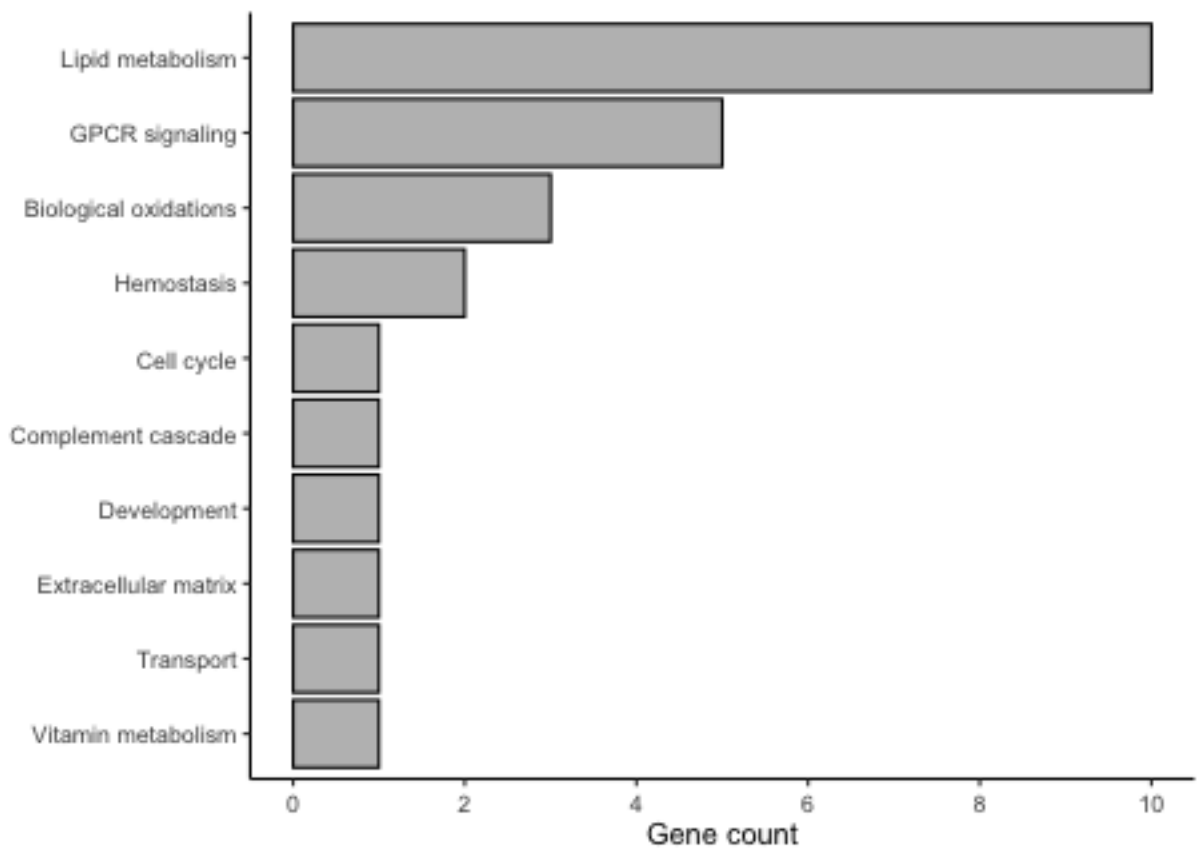
reactome_pathways.long <- pivot_longer(reactome_pathways.2, cols=1:24)
intersect_pathways_symbols <- reactome_pathways.long %>% filter(value %in% symbols) %>% unique()
intersect_pathways_symbols_counts <- as.data.frame(table(intersect_pathways_symbols$name))

order.GSEA.pathways <- as.data.frame(table(intersect_pathways_symbols$name)) %>%
  arrange(-Freq) %>%
  dplyr::pull("Var1") %>%
  as.vector()
```

```
str(order.GSEA.pathways)
```

```
## chr [1:10] "Lipid metabolism" "GPCR signaling" "Biological oxidations" ...
```

```
ggplot(intersect_pathways_symbols) +
  geom_histogram(aes(x=factor(name, levels=rev(order.GSEA.pathways))), stat="count", fill="grey", color="black") +
  coord_flip() +
  theme_classic() +
  theme(axis.text.x = element_text(vjust = .5)) +
  xlab("") +
  ylab("Gene count") +
  scale_y_continuous(limits = c(), breaks=c(0,2,4,6,8,10))
```



```
library(clusterProfiler)
options(connectionObserver = NULL)
# Warning: call dbDisconnect() when finished working with a connection
library(org.Mm.eg.db)

unique_symbols <- K27_GE_long_group_plot_filt$symbol %>% unique()
length(unique_symbols)
```

```
## [1] 45
```

```
GO_BP <- enrichGO(gene = unique_symbols,
  keyType           = 'SYMBOL',
  OrgDb             = org.Mm.eg.db,
  ont               = "BP",
  pAdjustMethod     = "BH",
  pvalueCutoff      = 0.05,
  qvalueCutoff      = 0.05,
  minGSSize         = 1,
  readable          = F,
  universe          = TPM_filt$symbol) # Can also use all expressed genes here instead.
head(as.data.frame(GO_BP))
```

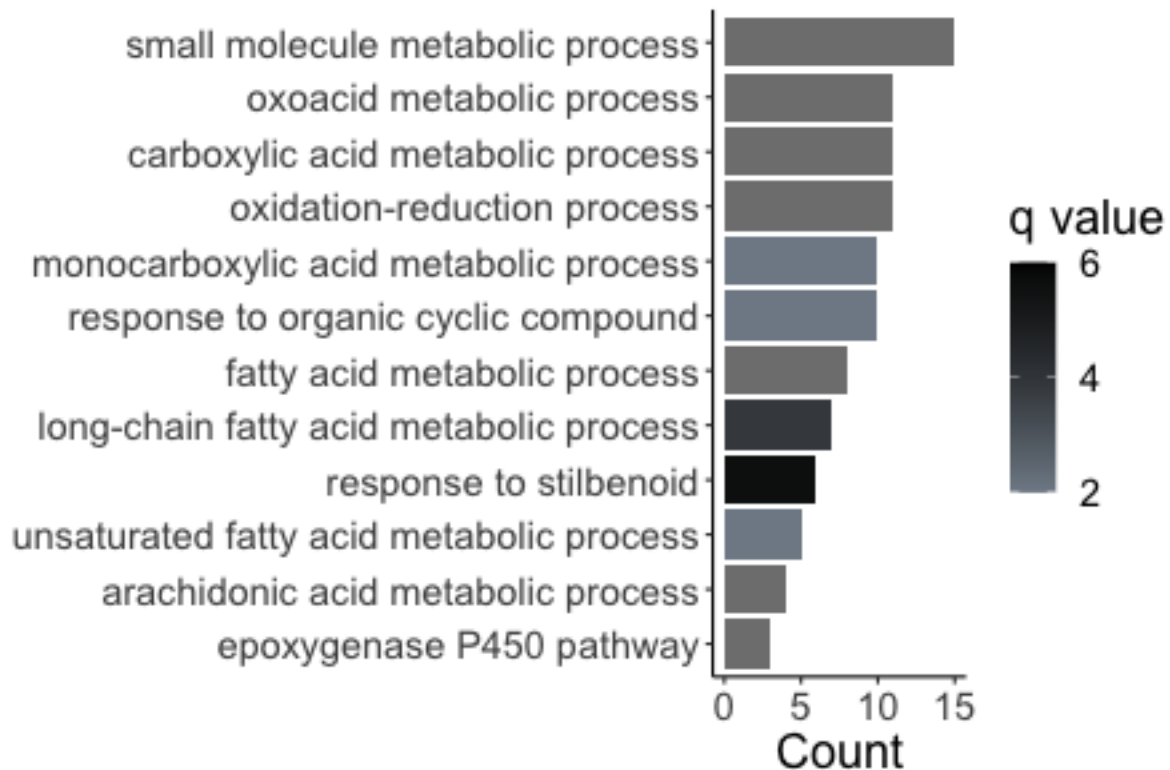
```
##              ID              Description GeneRatio
## GO:0035634 GO:0035634      response to stilbenoid      6/43
## GO:0001676 GO:0001676  long-chain fatty acid metabolic process      7/43
## GO:0014070 GO:0014070      response to organic cyclic compound      10/43
## GO:0032787 GO:0032787  monocarboxylic acid metabolic process      10/43
## GO:0033559 GO:0033559  unsaturated fatty acid metabolic process      5/43
## GO:0006631 GO:0006631      fatty acid metabolic process      8/43
##              BgRatio      pvalue      p.adjust      qvalue
## GO:0035634    9/2553 1.290065e-09 2.124737e-06 1.822386e-06
## GO:0001676   27/2553 1.603143e-07 1.320188e-04 1.132325e-04
## GO:0014070  124/2553 2.490001e-05 9.463098e-03 8.116498e-03
## GO:0032787  124/2553 2.490001e-05 9.463098e-03 8.116498e-03
## GO:0033559   23/2553 2.872829e-05 9.463098e-03 8.116498e-03
## GO:0006631   89/2553 8.477759e-05 2.327145e-02 1.995992e-02
##
##              geneID
## GO:0035634      Slc22a7/Hsd3b5/Cyp2b9/Cyp2a5/Cd36/Gsta2
## GO:0001676      Acot2/Cyp2b9/Cyp2a5/Cyp2a22/Acot4/Cyp4a10/Cd36
## GO:0014070      Inhba/Slc22a7/Gna14/Hsd3b5/Ncor2/Cyp2b9/Cyp2a5/Cdh1/Cd36/Gsta2
## GO:0032787      Mthfd1l/Acot2/Abcd2/Cyp2b9/Cyp2a5/Cyp2a22/Acot4/Mpc1/Cyp4a10/Cd36
## GO:0033559      Abcd2/Cyp2b9/Cyp2a5/Cyp2a22/Cyp4a10
## GO:0006631      Acot2/Abcd2/Cyp2b9/Cyp2a5/Cyp2a22/Acot4/Cyp4a10/Cd36
##              Count
## GO:0035634      6
## GO:0001676      7
## GO:0014070     10
## GO:0032787     10
## GO:0033559      5
## GO:0006631      8
```

```
View(as.data.frame(GO_BP))
```

```
library(dplyr)
library(ggplot2)
plot_me_ordered <- GO_BP[order(GO_BP$p.adjust), ]
plot_me_ordered <- plot_me_ordered[1:12, ]
plot_me_ordered <- plot_me_ordered[order(plot_me_ordered$Count), ]
name_order <- plot_me_ordered %>%
  dplyr::pull("Description")

ggplot(plot_me_ordered, aes(x=factor(Description, levels=name_order), fill=-log10(p.adjust), y=Count)) +
  geom_bar(stat="identity") +
```

```
coord_flip() +
scale_fill_gradient(name="q value", low = "#808b96", high = "black",
limits = c(2, 6), breaks = c(2, 4, 6))+
theme_classic() +
theme(text=element_text(size = 18)) +
ggtitle("") +
xlab("")
```



```
sessionInfo()
```

```
## R version 4.0.3 (2020-10-10)
## Platform: x86_64-apple-darwin17.0 (64-bit)
## Running under: macOS Big Sur 10.16
##
## Matrix products: default
## BLAS: /Library/Frameworks/R.framework/Versions/4.0/Resources/lib/libRblas.dylib
## LAPACK: /Library/Frameworks/R.framework/Versions/4.0/Resources/lib/libRlapack.dylib
##
## locale:
## [1] en_US.UTF-8/en_US.UTF-8/en_US.UTF-8/C/en_US.UTF-8/en_US.UTF-8
##
## attached base packages:
## [1] stats4 parallel stats graphics grDevices utils datasets
## [8] methods base
##
```



```

## other attached packages:
## [1] clusterProfiler_3.18.1 ggpubr_0.4.0          biomaRt_2.46.3
## [4] org.Mm.eg.db_3.12.0    AnnotationDbi_1.52.0    Biobase_2.50.0
## [7] ChIPpeakAnno_3.24.2    GenomicRanges_1.42.0    GenomeInfoDb_1.26.7
## [10] IRanges_2.24.1         S4Vectors_0.28.1       BiocGenerics_0.36.1
## [13] forcats_0.5.1          stringr_1.4.0           dplyr_1.0.6
## [16] purrr_0.3.4            readr_1.4.0            tidyr_1.1.3
## [19] tibble_3.1.2           ggplot2_3.3.3          tidyverse_1.3.1
##
## loaded via a namespace (and not attached):
## [1] utf8_1.2.1             tidyselect_1.1.1
## [3] RSQLite_2.2.6          grid_4.0.3
## [5] BiocParallel_1.24.1    scatterpie_0.1.5
## [7] munsell_0.5.0          withr_2.4.2
## [9] colorspace_2.0-1       GOsemSim_2.16.1
## [11] highr_0.9              knitr_1.33
## [13] rstudioapi_0.13        ggsignif_0.6.1
## [15] DOSE_3.16.0            MatrixGenerics_1.2.1
## [17] labeling_0.4.2         GenomeInfoDbData_1.2.4
## [19] polyclip_1.10-0        bit64_4.0.5
## [21] farver_2.1.0           downloader_0.4
## [23] vctrs_0.3.8            generics_0.1.0
## [25] lambda.r_1.2.4         xfun_0.31
## [27] BiocFileCache_1.14.0   regioneR_1.22.0
## [29] R6_2.5.0               graphlayouts_0.7.1
## [31] AnnotationFilter_1.14.0 bitops_1.0-7
## [33] cachem_1.0.5           fgsea_1.16.0
## [35] DelayedArray_0.16.3    assertthat_0.2.1
## [37] scales_1.1.1           ggraph_2.0.5
## [39] enrichplot_1.10.2      gtable_0.3.0
## [41] tidygraph_1.2.0        ensemblDb_2.14.0
## [43] rlang_0.4.11           splines_4.0.3
## [45] rtracklayer_1.50.0     rstatix_0.7.0
## [47] lazyeval_0.2.2         broom_0.7.6
## [49] BiocManager_1.30.12    yaml_2.2.1
## [51] reshape2_1.4.4         abind_1.4-5
## [53] modelr_0.1.8           GenomicFeatures_1.42.3
## [55] backports_1.2.1        qvalue_2.22.0
## [57] RBGL_1.66.0            tools_4.0.3
## [59] ellipsis_0.3.2         RColorBrewer_1.1-2
## [61] Rcpp_1.0.6             plyr_1.8.6
## [63] progress_1.2.2         zlibbioc_1.36.0
## [65] RCurl_1.98-1.3         prettyunits_1.1.1
## [67] openssl_1.4.4          viridis_0.6.1
## [69] cowplot_1.1.1          SummarizedExperiment_1.20.0
## [71] haven_2.4.1            ggrepel_0.9.1
## [73] fs_1.5.0              magrittr_2.0.1
## [75] data.table_1.14.0      futile.options_1.0.1
## [77] DO.db_2.9              openxlsx_4.2.3
## [79] reprex_2.0.0           ProtGenerics_1.22.0
## [81] matrixStats_0.58.0     hms_1.1.0
## [83] evaluate_0.14          XML_3.99-0.6
## [85] VennDiagram_1.6.20     rio_0.5.26
## [87] readxl_1.3.1           gridExtra_2.3

```

| | |
|-----------------------------------|-------------------|
| ## [89] compiler_4.0.3 | shadowtext_0.0.7 |
| ## [91] crayon_1.4.1 | htmltools_0.5.1.1 |
| ## [93] mgcv_1.8-34 | lubridate_1.7.10 |
| ## [95] DBI_1.1.1 | tweenr_1.0.2 |
| ## [97] formatR_1.9 | dbplyr_2.1.1 |
| ## [99] MASS_7.3-53.1 | rappdirs_0.3.3 |
| ## [101] Matrix_1.3-3 | car_3.0-10 |
| ## [103] cli_3.2.0 | igraph_1.2.6 |
| ## [105] pkgconfig_2.0.3 | rvcheck_0.1.8 |
| ## [107] GenomicAlignments_1.26.0 | foreign_0.8-81 |
| ## [109] xml2_1.3.2 | multtest_2.46.0 |
| ## [111] XVector_0.30.0 | rvest_1.0.0 |
| ## [113] digest_0.6.27 | graph_1.68.0 |
| ## [115] Biostrings_2.58.0 | rmarkdown_2.14 |
| ## [117] cellranger_1.1.0 | fastmatch_1.1-0 |
| ## [119] curl_4.3.1 | Rsamtools_2.6.0 |
| ## [121] lifecycle_1.0.0 | nlme_3.1-152 |
| ## [123] jsonlite_1.7.2 | carData_3.0-4 |
| ## [125] futile.logger_1.4.3 | viridisLite_0.4.0 |
| ## [127] askpass_1.1 | BSgenome_1.58.0 |
| ## [129] fansi_0.5.0 | pillar_1.6.1 |
| ## [131] lattice_0.20-41 | KEGGREST_1.30.1 |
| ## [133] fastmap_1.1.0 | httr_1.4.2 |
| ## [135] survival_3.2-10 | GO.db_3.12.1 |
| ## [137] glue_1.6.2 | zip_2.2.0 |
| ## [139] png_0.1-7 | bit_4.0.4 |
| ## [141] ggforce_0.3.3 | stringi_1.6.2 |
| ## [143] blob_1.2.1 | memoise_2.0.0 |